greatest admiration is due to the skillful inventors who, by proper compensation, have been able to reduce the rates to quantities which are insensible as compared with the foregoing.

On the hypothesis that our chronometer is a sidereal chronometer, the zero-point—i. e., the temperature for which the chronometer has no rate whatever, places itself at 54°.7. Accordingly, if we consider the chronometer to give mean solar time, the zero-point will be 69°.2. I reserve a more complete discussion to some future time, when the final results shall have been attained.

BERKELEY, CAL., March, 1891.

THE SYSTEM OF THE STARS.*

BY GEORGE E. HALE.

The rise and progress of Stellar Astronomy have been so rapid that, of necessity, its literature is almost wholly confined to the papers scattered through the publications of observatories and the various astronomical journals. It is, therefore, pleasant to find a large amount of this material collected together into a single volume, and entertainingly woven into a connected narrative. There are few observations or theories of importance within the range of her work which Miss CLERKE has not touched upon, and, though at times she rather summarily dismisses views at variance with her own, it may be said, in general, that opinions of any weight are accorded reasonable recognition. The plan of the book is to lead by gradual steps from the individual to the general, passing from single stars and nebulæ to double and multiple systems, and reaching, finally, the crowning problem of the construction of the heavens.

The first chapter brings forcibly before the mind the unbounded scope of astronomical investigation in a general account of the number and distribution of the stars, and devotes, in passing, considerable space to an explanation of scintillation. In the second chapter the methods of research are briefly pointed out, and the recent important developments of stellar photometry, photography and spectroscopy are clearly described. "Sirian and Solar Stars" form the subject of the third chapter, and here we are

* The System of the Stars; by Miss AGNES M. CLERKE, London, 1890, 8vo.

introduced to a theory, proposed by Miss CLERKE, to account for the atmospheric conditions of these numerous bodies.

From the early days of stellar spectroscopy to the present, the stars of SECCHI'S first type have been considered to represent the maximum limit of temperature among the heavenly bodies, and the peculiarities of their spectra are supposed to depend upon this high degree of heat. Characterized as they are by the prominent absorption lines of hydrogen in the ultra-violet, they are connected with the solar stars by intermediate bodies in which "the conspicuousness of rays due to absorption by ordinary metals * * * varies inversely with that of the hydrogen series" (p. 42). But some stars, while possessing an ultra-violet spectrum which entitles them to a place between *Sirius* and the sun, exhibit certain marked peculiarities. These constitute SCHEINER'S Class I b, which includes β *Orionis*, ϵ *Orionis* and α *Cygni*. Their spectra contain comparatively few lines in the visible portion, while in the blue, violet and ultra-violet the numerous lines are all of about equal width, though their intensities are very different, the hydrogen series in α *Cygni* standing out prominently on the HARVARD photographs from a background of fainter lines. Dr. SCHEINER has shown that the spectrum of this star has very little similarity with that of the sun, for although a large number of iron lines agree fairly in position, the force of these coincidences is greatly decreased by the remarkable differences in intensity.* Miss CLERKE has been criticised for classing these with *Sirian* stars† on the ground that the nature of the "Orion stars" must be influenced by the presence of the nebulæ, but her critic seems to have overlooked the fact that she follows Dr. SCHEINER in placing α *Cygni* with the "Orion Stars," and in this case his reason for separate classification does not hold. If Mr. FOWLER would refer to Dr. SCHEINER'S description and measures of the spectrum of α *Aquilæ*, he would find that the author places it, with good reason, nearly midway between *Sirian* and solar stars. Although it is by no means impossible that solar stars should be divided into two groups, on the basis of increasing or decreasing temperature, the separation indicated by Mr. FOWLER is evidently not free from objections.

It should be noted on p. 44 that AMES has found the fifth

* Scheiner Die Spectralanalyse der Gestirne, p. 272.

† Nature, December 25, 1890.

hydrogen line (near H) to be absent from the solar spectrum,* and it might also be mentioned here that a mistake is made on p. 38, in the statement that CORNU obtained the entire hydrogen series, for the tables in the paper referred to do not contain the very last line of the series. It is an interesting fact that AMES was unable, under any conditions, to obtain the "Stellar Series" without the "secondary" spectrum investigated by HASSELBERG.†

Miss CLERKE rightly gives prominence to the value of conclusions drawn from the appearance of the K line in stellar spectra, but the immediate application to her theory of electrical repulsion can hardly be so easily allowed. In the first place, as will be shown more in detail in a subsequent paper, the statement that "so far as terrestrial experiments can inform us, it (the substance emitting both H and K) arises as a modification of the metal calcium only under the strongest electrical excitement," on p. 45, is incorrect, for I have recently photographed both lines at the temperature of burning magnesium wire, and photographs of the spectrum of calcium chlorides in the BUNSEN flame, probably, also show both of them faintly. It is true that they are not strongly developed under these conditions, but it is, at the same time, evident that the calcium molecule, as it exists in the flame, does not require to be dissociated to produce the lines in question. The variations in the intensity of H and K are entirely analogous to the variations of the blue calcium line at $\lambda 4226.3$, and in this case we know that the greatest intensity does not correspond with the strongest electrical excitement, for the intensity reaches a maximum in the electric arc, and is decreased with an increase of the current. At the high temperature of the high tension electric spark the intensity is still further decreased, and in the solar spectrum the blue line is of small importance as compared with H and K. It seems very probable that the intensity changes of H and K can be traced almost entirely to conditions of temperature, though the secondary effect of electricity is not necessarily excluded. These lines are weak at low temperatures, but increase steadily in strength up to their maximum development in *Arcturus*. Further increase of temperature acts with them as with the blue line in the arc, until it seems possible, although contrary to the belief of Professor LOCK-

* Phil. Mag. [5], v. 30, No. 182, p. 54.
† Ibid, p. 52.

YER and others, that H may have about the same strength as K in the hottest stars, but appears broader and more intense on account of the overlying hydrogen line. This last point is, however, of little importance here, and we may consider with Miss CLERKE only the K line. It will be seen that from this point of view there is little argument for her theory that the *Sirian* stars are developed from solar stars by a decrease of the electrical repulsion in their atmospheres, and a consequent precipitation of the heavier constituents to the level of the photosphere. A single case will show that reasoning, based on the strength of K, must be fallacious. On p. 48 *Arcturus* is shown to be at a higher temperature than the sun by the presence in its spectrum of six out of the nine lines in the ultra-violet hydrogen series. This would give it a place between *Sirius* and the sun, and, on Miss CLERKE'S theory, the electrical repulsion in the atmosphere would be less than that in the surroundings of the sun. But the author also supposes the electrical repulsion to be directly proportional to the strength of K, and K in *Arcturus* is even more prominent than the same line in the sun (p. 47); thus the results reached from the two points of view directly contradict each other.

The arguments brought forward by Dr. HUGGINS in his Bakerian lecture on the corona* are strongly in support of an electrical repulsion acting outward from the sun, but in using a similar view to account for the phenomena of stars of different types, Miss CLERKE holds only the one fact of an electrical repulsion in common with Dr. HUGGINS. The latter, from his long and varied experience in stellar and solar spectroscopy, believes that the sun is reducing its temperature; that the electrical repulsion increases with an increased activity on the surface, and was, consequently, greater at the higher temperature of the Sun, in early geological times.† Miss CLERKE, on the contrary, holds that the sun is increasing in temperature, and that the electrical repulsion decreases as the temperature increases. As the former view is in direct opposition to the belief of most of the best solar physicists, and as the latter contradicts the author of the theory on which it is based, it will be admitted that the electrical theory of the stars must be regarded with some degree of hesitation. The electrical theory has many points in common with the views of Mr. G. J. STONEY, referred to in the text (p. 50), and the question of vapor

* Proc. R. S., No. 239, p. 108.

† Loc. cit., p. 134.

density occupies about the same position in both cases. So far as the *Sirian* stars are concerned, the identification of the less prominent lines with lines of iron, sodium, calcium and magnesium is exactly what Dr. STONEY,* and, probably Miss CLERKE, as well, were led to expect from a consideration of the probable vapor densities of these metals. But it may be noted that most of these same metals have been among the first recognized in stars of SECCHI'S second and third types, as well as in the first.

Leaving, for a time, this portion of the problem of stellar evolution, let us turn our attention to the discussion of stars with banded spectra given in Chapter IV. Starting out with an exalted scale of temperature in mind, the statement on p. 52 that "isolated rays of definite wave-lengths, forming in the spectrum what we call 'lines,' bright or dark, are emitted only at very high temperatures," is a curious one to every reader who knows the low degree of heat necessary to bring out lines in the spectra of many substances. Such statements as this could hardly mislead, but more attention should be paid to accuracy, especially when about to take up the difficult and important subject of the red stars.

The investigations of HUGGINS, VOGEL and DUNÉR on the visual, and of PICKERING and SCHEINER on the photographic spectra of the third type stars have shown that beneath a strongly marked system of absorption flutings a line spectrum is undoubtedly present, which is so similar to the solar spectrum that there can be little doubt but that one type results from the other by some process of evolution. A marked peculiarity of third type spectra is in the fact that several of the flutings are terminated by sharp, metallic lines, and for this no explanation has yet been offered. Dr. SCHEINER has also found that many lines are hazy on one side and sharp on the other, and whatever may be its cause, this appearance is certainly very similar to that of the individual lines in the flutings of some metallic oxides. There can be no question but that the third type spectra are strongly indicative of a comparatively low temperature. Whether, as Miss CLERKE would have us believe, the photosphere is about of the same degree of heat as the photosphere of our sun, while the fluting absorption takes place in the cooler regions of a very extensive atmosphere, cannot as yet be definitely answered, but our author brings forward some excellent reasons in support of such a view.

* Proc. R. S , v. 17, p. 50.

The fact that absorbing calcium lies above radiating hydrogen in *Mira Ceti* is well illustrated in an excellent reproduction of a DRAPER Memorial photograph of the spectrum of this star. The exponents of the meteoritic hypothesis find it very difficult to account for this condition of things, and, in fact, a careful consideration of third type spectra does not lead one to the belief that they can all be accounted for by the collisions of meteor swarms. On the contrary, as Dr. SCHEINER has remarked in his recent work, the greater the accuracy brought to bear in a study of this hypothesis, the more untenable do its foundation principles become. Mr. FOWLER has complained because of Miss CLERKE'S failure to mention a few observations which go to prove the presence of certain of the bright carbon flutings in the spectra of α *Herculis*, *Mira Ceti* and *Nova Orionis*, and perhaps these should have been alluded to. But it is admittedly true that in the great majority of the third type stars the difficulty of demonstrating the presence of bright carbon is almost, if not quite, insuperble, whether the reasoning be based on the effects of masking and contrast, or on actual comparisons with high dispersion at the telescope. Professor LOCKYER has explained that the "three figure notation" used in his earlier publication was merely provisional, and if the hypothesis is to stand, it must admit of measures comparable in accuracy with those demanded in solar work. In the case of the much-discussed chief nebular line such measures have been made, and the result is a high improbability that magnesium, whether free or in combination, is responsible for the line. In other words, the first serious attack upon the hypothesis has served to weaken it, and the recent work of Dr. and Mrs. HUGGINS on the WOLF-RAYET stars in *Cygnus* is another step in the same direction.

If third type stars are, in reality, characterised by great atmospheric extension, the electrical repulsion theory offered by Miss CLERKE seems to supply a possible explanation, but its probability is open to considerable question. Dr. SCHEINER has referred to a marked similarity between third type and sun-spot spectra, and finds a possible explanation of variability on this basis. But, in spite of the great mass of information already gathered in regard to stellar spectra, the dispersion has been so low in almost all cases that it seems best to defer judgment until greater certainty is secured in a far more comprehensive investigation than has yet been undertaken. It cannot fail to be noted that the

majority of the best spectroscopists are extremely conservative, and few of them hazard a general explanation of the complicated problem, whose great extent they so fully realize.

The faintness in fourth type stars is so great a hindrance to spectroscopic investigation that, as yet, the secondary elements of their spectra are but little known. The few lines measured point to a probability of iron, but nothing is thoroughly well known about these stars, except the certain presence of carbon, as signified by its strongly marked absorption flutings. Dr. SCHEINER gives a few lines which seem to be common to α *Orionis* and the fourth type stars, and on the strength of this he believes that SECCHI'S third and fourth types should not be completely set apart, but classed as subdivisions of the same type, the marked differences in their spectra being brought about by unexplained differences in the chemical combinations in their atmospheres.* But, if we except a single doubtful instance of little weight, there seem to be no examples of stars marking the transition stage from the second to the fourth type, while the second and third are clearly connected. Mr. FOWLER urges a suggestion of Professor LOCKYER'S that the secondary lines in the fourth type are indicative of such absorption as take place in our own atmosphere, and cites the presence of carbon in the sun to connect the fourth type with solar stars, assigning a lower position to the former on the descending branch of the temperature curve. Miss CLERKE believes that the strong absorption in fourth type stars is accompanied by "imperfect condensation" in an atmosphere of great depth, while the photosphere is in a state of "powerful incandescence" (p. 64). She does not use her electrical theory to account for this peculiar class of bodies, and wisely omits a speculative discussion of their origin.

In Chapter V we come to what may probably be called the most interesting field of spectroscopic astronomy—the gaseous stars and nebulæ. In the explanation of stellar bright lines Miss CLERKE is decidedly opposed to the view of Dr. SCHEINER that they result from the fact that the radiations from "enormous self-luminous atmospheres" would "predominate simply through quantitative excess over the continuous radiance of comparatively small nuclei." While Dr. SCHEINER believes in an increased absorption of hydrogen in the denser strata near the photosphere of γ *Cassiopeiæ*, the author urges that "the fineness of other dark

* Spec. der Gestirne, p. 321.

lines in the same spectrum implies an atmosphere tenuous throughout" (p. 64), though on the next page Professor PICKERING'S discovery of the double reversal of the hydrogen lines in *Pleione* is mentioned, with the remark that "an absorbing stratum is placed beneath a more vividly incandescent bed of the same substance, and the condition partially indicated in γ *Cassiopeiæ* is fully attained." The peculiarity in this condition of things lies in the fact that *Pleione* is usually classed in the first type, and, although a denser stratum of hydrogen near the photosphere is thus rendered probable, it is by no means easy to draw a general conclusion applicable to third type stars. As calcium is known to lie above the brilliant hydrogen in *Mira Ceti*, the elements producing the "other dark lines" may, in some similar way, be without the region of greater pressure. It is next stated that "the phenomena of spectral variability appear entirely inconsistent with this rationale. Fluctuations in atmospheric extent, even if we could admit their occurrence on the incredible scale and with the incredible swiftness required, would not account for the *relative* variability of bright lines." It is posssible that fluctuations in atmospheric extent are not involved in spectral variability, but the changes in spectra must be much better known than at present, before they can be used as an argument on either side of the question. The last objection offered by Miss CLERKE against Dr. SCHEINER'S view, is in the great number of bright lines found by Dr. BECKER in the spectrum of β *Lyræ*. The alleged difficulty is, that an atmosphere of such "heterogeneous constitution" could not rise to so great an elevation above the photosphere. (p. 68.) But, with increased skill in the method of attack, the spectrum of the *Orion* nebulæ has been found to be more and more complicated, the complexity of bright lines originating at enormous distances from the probable center of condensation in the trapezium. Here, then, is an atmosphere of complex constitution, rising to altitudes far greater than any required by Dr. SCHEINER, and, though condensation is evidently further advanced in β *Lyræ*, there may still remain an extensive and brilliant atmosphere. Nothing can be of greater interest or value than a careful study of the simultaneous variations in the spectrum and light of such a variable as β *Lyræ*. As remarked on page 69, it is not improbable that changes in general absorption are involved, and photometric measures of different parts of the continuous spectrum are, therefore, desirable.

The recent investigations of Dr. and Mrs. HUGGINS have directed renewed attention to the interesting stars of the WOLF-RAYET type. Probably because of the small dispersion of his instrument, Mr. FOWLER found the blue band in the spectrum of the three stars in *Cygnus* to agree exactly in position with the blue band of carbon in the flame, and from this comparison Professor LOCKYER drew his main argument to prove that bright-line stars are "nothing more than swarms of meteorites a little more condensed than those which we know as nebulæ." * But the previous observations of VOGEL could not be reconciled with this view, and the measures and direct comparisons of Dr. and Mrs. HUGGINS were undertaken with considerable dispersion, in order to clear up the question. The result is that the blue band in the four stars observed agrees neither in position nor character with the blue carbon fluting, and as no brightenings in the spectra were detected at the positions of the other carbon bands, there seems to be no reason to believe that carbon exists in the atmospheres of the WOLF-RAYET stars.† The chief argument for the meteoric constitution of these bodies is thus destroyed. Miss CLERKE does not here refer to Professor LOCKYER'S "meteoritic hypothesis," and, for some reason, omits to bring forward her own electrical theory, or any other explanation of bright-line stars of this type.

On page 49 the spectral variations of the "*Orion* stars" are made to connect the first and second types, and it is remarked that "the dividing-line, rendered difficult to draw by the occurrence of intermediate examples, is still further effaced by the swinging across it of a few unstable objects." The statement met with on page 72 expresses a different view. "The brilliant stars of *Orion* may be said to mark the first stage on the road toward nebulosity. For their spectra appear at times unbroken by the traces of hydrogen-absorption, more or less strongly impressed upon them at others; and the transition is an easy one from this state of things to that existing in β *Lyræ*, where the same sort of fluctuating balance of temperature inclines preferentially the other way. That is to say, the hydrogen atmosphere of this star tends to rise above the thermal level of its photosphere. Emissive superiority is substituted for neutrality, and gains more and more the upper hand, as gaseous stars merge into undoubted nebulæ."

* Nature, v. 42, p. 344.

† Sidereal Messenger, February, 1891.

Certainly, the line of evolution indicated in the two cases is markedly different, and the author seems to be open to the charge of inconsistency, urged on the same point by Mr. FOWLER.

The account given by Dr. HUGGINS of his observations of the spectrum of Comet I, 1866, seems to indicate that no very elaborate precautions were taken to insure great accuracy, and, indeed, the low degree of dispersion would have rendered them useless.* But whether the chief nebular line was present or not, there seems to be some reason to believe that comets and nebulæ are in some way related. Even if a very intimate relationship were assumed, however, it is by no means proved that nebulæ are the visible results of the collisions of swarms of meteorites, for it is not even yet proved satisfactorily that comets are of meteoric nature. The long and laborious investigations of nebular spectra which have been carried on by Professor LOCKYER, Dr. HUGGINS, Mr. KEELER and others, have resulted in valuable negative evidence, though we are, as yet, entirely in the dark as to the true origin of the principal line. Miss CLERKE concludes (p. 77) that the nebulæ "are not greatly heated," and, in this respect, she is in general agreement with Professor LOCKYER. But, on this view, how is the presence of α and β of the hydrogen series in the *Orion* nebulæ to be accounted for? (Is not the note at the foot of page 78, stating that the "entire series" was photographed by Dr. and Mrs. HUGGINS, incorrect?) It seems probable that a considerable degree of heat, or electrical excitement, is necessary to the production of any of the lines in the ultra-violet series, and Dr. and Mrs. HUGGINS believe that the nebulæ "consists probably of gas at a high temperature and very tenuous, where chemical dissociation exists, and the constituents of the mass, doubtless, are arranged in the order of vapor-density.† The pressure of the D_3 line, found only in the very hottest regions of the sun, is of the greatest importance in this connection. In her review of the present volume Mrs. HUGGINS has stated that recent investigations on the *Andromeda* nebula show that the continuous spectrum does not end abruptly in the orange, as stated on page 81, but fades away gradually into the red. As remarked, at the close of the chapter, there are undoubtedly great possibilities in future investigations of the apparently "continuous" spectra of the nebulæ.

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* Proc. R. S., v. 15, p. 5.

† Proc. R. S., v. 46, p. 59.

The belief has long been held that stars are evolved in the lapse of ages, from the elementary condition of the nebulæ, but striking proofs were lacking until very recently. Perhaps no two things could bring the subject more forcibly to our attention than Mr. ROBERT'S magnificent photograph of the *Andromeda* nebula, and the discovery of Dr. and Mrs. HUGGINS that the stars in the trapezium of *Orion* are really in organic connection with the great mass of nebulous matter surrounding them. Here is a foundation upon which to build, and Miss CLERKE is doubtless justified in her remark that "gaseous stars take their rise almost insensibly from planetary nebulæ, and themselves merge into unmistakeable suns," though Professor PICKERING'S distinct separation from all other stars of his fifth type, containing bright-line stars and planetary nebulæ,* shows that the course of development is not yet clear. Many considerations make it probable that if any system of stellar classification is to be of more than merely empirical value, it must start from the condition of the nebulæ, and here the careful grouping of VOGEL is deficient. There are other objections to the same system; for instance, the much-discussed groupings of the third and fourth types. If the line of evolution really divides just after the solar stage is passed, there certainly should be found some example of spectra intermediate between the second and fourth types. Although it was thought by DUNÉR that he had found one such star, its feeble brilliancy allowed no degree of accuracy in the investigation of its spectrum, and no connecting examples are known with sufficient definiteness to afford much ground for argument. Miss CLERKE, indeed, believes that the third and fourth types cannot "be set far apart in the developmental series" (p. 89), but her views are not substantiated by any well-founded arguments, and, for the present, at least, the fourth type stars should probably be considered by themselves. If this is done, of course no complete line of evolution can be developed, for in any system of value no objects of any importance can be left out. But this conclusion is not to be regretted, for a crowd of incomplete and defective hypotheses, though each may point out certain interesting relationships, can bear no comparison in value with a comprehensive scheme of evolution, deliberately and carefully worked out, and embodying the results of the most searching investigation. It is thus best, at present, not to be too positive in statements based upon observa-

* Fourth Annual Report HENRY DRAPER Memorial, p. 8.

tions made with limited or insufficient instrumental means, for future researches are more than likely to show that they are entirely unfounded.

But, although she does not try to cover all the ground, can even the partial line of evolution mapped out by the author be considered of a very satisfactory nature? Starting out with stars of the third type, and pursuing the rising branch of a temperature curve not unlike that of Professor LOCKYER, the solar and *Sirian* stage are successively passed through. The sun is thus supposed to be rising in temperature, the reasoning being based on the belief that atmospheric extent is inversely proportional to age, while the sun is considered to have a less extensive atmosphere than *Sirius*. The electrical theory is once more brought into play, with the conclusion that the sun will be, at some future day, a star like *Vega* or *Castor* (p. 90). Whatever the objections which might be raised against the principles involved in this reasoning, it is safe to agree that "the line of stellar evolution indicated by recent inquiries, is from red stars with banded spectra, through yellow stars with metallic lined spectra, to white stars distinguished by almost exclusive hydrogen atmosphere," if "stars of the third type" be substituted for "red stars with banded spectra" (p. 92). Beyond this, the extensive investigations of Professor E. C. PICKERING show that it is unsafe to go.*

The temperature curve drawn by Miss CLERKE rises easily to the maximum, but, in endeavoring to descend, it seems to meet with serious obstacles. Although it is stated at the opening of the chapter that "among the hosts of heaven we may expect to find * * * stars still effective as radiators, though of declining powers," the author does not find the expectation realized, so far as the spectroscope is concerned, and, in lack of observation, she feels compelled to predict a new spectral type, exemplified by the, as yet unknown, spectrum of the satellite of *Sirius*. "There is a strong probability, however, that the light of the dim component will prove, on analysis, to be of an undistinguished character, interrupted neither by bands nor conspicuous dark lines, and feeble, not through effects of absorption, but intrinsically" (p. 92). It seems strange that, if such a type exists, it has not been discovered in the thousands of photographs and observations of stellar spectra which have been recorded. The probably fatal objections to any such characteristics of the spectra of cooling

* Fourth Annual Report HENRY DRAPER Memorial, p. 8.

stars have been well given by Mr. FOWLER in the review already referred to. The changes of condition incident to the cooling of stars like *Sirius* must be made manifest by gradual changes in spectrum, and in some way the hydrogen lines must disappear. If the "electrical repulsion" were supposed to continue to decrease on the plan already mapped out for it, the line of hydrogen would presumably grow broader and, finally, fainter, while the other lines of the spectrum entirely disappeared. But there seems to be not the slightest reason to believe that this is the case. If, on the other hand, the hydrogen lines became progressively finer, an increased prominence of the metallic lines might be expected. In fact, it is difficult to see anything of value in Miss CLERKE'S hypothetical stellar type, and the downward branch of the temperature curve is still an enigma.

The next three chapters deal with the temporary and variable stars, and one's interest cannot fail to be aroused by a most readable account of these remarkable bodies. From a spectroscopic point of view, the light changes in *Nova Cygni* are most significant, and the ascendancy of the chief nebular line with the decline in brilliancy of the star, must be well taken into account in endeavors to explain the phenomenon. Professor LOCKYER'S meteoric explanation has the great advantage of fitting in with the fact of very rapid cooling, but other considerations show that it is probably safer to replace his postulates of two colliding meteor swarms by the more indefinite phrase, "masses of nebulous matter," or, as Miss CLERKE has done, by a comet and a nebulous star (p. 107). At the same time, a host of other explanations have been brought forward by ZÖLLNER, LÖHSE, WILSING and others, and, though these are not referred to by Miss CLERKE, they deserve some consideration. As is properly urged, it seems more than probable that temporary and variable stars are closely related in nature, and the causes involved cannot presumably be widely different in kind, however wide the separation in degree.

Variables of the *Mira Ceti* type next offer themselves for explanation, and several hypotheses are mentioned. Considerable attention is accorded Professor LOCKYER'S "collision theory," and its good and bad points are impartially pointed out. But no mention is made of the possibility of multiple swarms, with the complicated effects to which they might conceivably give rise, unless an obscure reference on page 127 be excepted. Instead, the author passes rapidly on to develop a theory based on an

analogy between the curves of sun-spot frequency and the light changes in variable stars. She believes that "the maximum of spots in the sun corresponds with the maximum of light in stars, and *vice versa.*" Accepting Professor LOCKYER'S theory that sun-spots are due to down-rushes of cooled matter upon the photosphere, she considers that the falls are vastly increased in number at spot-maximums, and the intense heat, accompanied by the development of great electrical force, account for the changes in brilliancy and spectrum. Seemingly, in order to connect this explanation with that given for temporary stars, the spot period is supposed to be controlled by an attendant body revolving in an orbit of dimensions determined by the atmospheric extension of the star. Tidal effect is also hinted at, and it would be a strange chance if this all-embracing explanation did not contain some grains of truth. This, however, does not vitiate the force of the statement that "the time has not come to formulate a theory of stellar variability" (p. 125). As to short-period variables, they seem to offer even greater difficulties than those of longer period, with the exception, of course, of the *Algol* type, which Dr. VOGEL'S spectrographic investigations have fully explained.

The interesting descriptive matter contained in the rest of the book calls for no particular discussion here, but it can be highly recommended as giving a valuable account of the general topics of stellar astronomy. The chapter on the colors of the stars renders very certain the belief that methods of observation much more reliable than those generally employed in the past, must precede conclusions of very great value. Double stars, variable doubles, stellar orbits and multiple stars occupy successive chapters. The *Pleiades* deservedly claim a chapter to themselves, before star clusters in general are taken up, and the results of recent investigation are entertainingly introduced by references to the legendary importance of this celebrated group. The next three chapters are devoted to the nebulæ, and reproductions of Mr. ROBERTS' photographs form excellent illustrations, with the unfortunate exception of the Great Nebula in *Andromeda*, which should have been the best of all. In the discussion of the nature and changes of the nebulæ the importance of the physical analogy between comets and nebulæ is pointed out, and it is insisted that electricity is involved as the illuminating power. This is by no means impossible, but it it hardly time to say that the nebular spectrum "probably includes no element of truly continuous

light" (p. 296). The distances of the stars, translation of the solar system, proper motions, the Milky Way, status of the nebulæ and the construction of the heavens, are the subjects treated of in the remaining portion of the work, and there are six valuable tables in the appendix.

In spite of its few defects, Miss CLERKE is to be congratulated upon a book which is excellent in the main. A fair discrimination, combined with a wide range of information and an attractive style, seem to be the chief elements in her deserved success.

KENWOOD PHYSICAL OBSERVATORY,
CHICAGO, March 21, 1891.

BY-LAWS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC.*

ARTICLE I.

This Society shall be styled the ASTRONOMICAL SOCIETY OF THE PACIFIC. Its object shall be to advance the Science of Astronomy, and to diffuse information concerning it.

ARTICLE II.

This Society shall consist of Active, Life, Corresponding and Honorary members, to be elected by the Board of Directors.

1. Active members shall consist of persons who shall have been elected to membership and shall have paid their dues as hereinafter provided.

2. Life members shall consist of persons who shall have been elected to life membership and shall have paid $50 (fifty dollars) to the Treasurer of the Society.

3. Corresponding members shall consist of persons not residing on the Pacific Coast, who shall have been elected as such.

4. Honorary members shall consist of persons specially distinguished for their attainments in Astronomy, not to exceed thirty in number, who shall have been elected as such.

Corresponding and Honorary members shall pay no dues, shall not be eligible to office, shall have no votes, and shall receive the Publications of the Society.

5. A certain number of Observatories, Academies of Science,

* For the convenience of new members, the By-Laws now in force are here printed.